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Strengthening Small-Scale Snakehead (Channa Striata) Aquaculture through the Implementation of the IoT-Based "Channa Sense" Monitoring System

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Abstract

Small-scale snakehead (Channa striata) farmers commonly rely on manual and periodic water quality monitoring, which often results in delayed responses to environmental fluctuations and high fry mortality rates. This community service program aimed to strengthen technological literacy and improve hatchery management practices through the implementation of an Internet of Things (IoT)-based "Channa Sense" real-time monitoring system. The intervention adopted a structured three-phase approach consisting of pre-implementation assessment, participatory workshop and system installation, and post-implementation evaluation. The program involved 37 participants representing farmers, entrepreneurs, and community members, with baseline data collected from 30 small-scale farmers across Palembang, Indralaya, and Musi Banyuasin. Pre-intervention findings showed that 56.76% of participants were unaware of the technology and none had prior experience with digital monitoring systems. Following experiential learning activities, 64.86% of participants reported a moderate to full understanding of the system, and recognition of Channa Sense as a water quality monitoring device increased from 13.51% to 60.42%. At the partner hatchery (Kandang Om Bobby), real-time monitoring reduced fry mortality from approximately 40% to 5–10%, representing a survival improvement of 30–35%. The findings indicate that participatory and context-adapted IoT interventions can effectively bridge digital literacy gaps while generating measurable operational benefits in small-scale aquaculture. However, adoption intentions remained moderate due to cost and maintenance concerns. Continued mentoring, cost optimization, and cooperative-based implementation strategies are recommended to ensure long-term sustainability and broader community uptake.

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INTRODUCTION

Aquaculture plays a vital role in addressing food security and ensuring the availability of high-quality fish (Boyd et al., 2022; Rowan, 2023). Fish is a primary source of animal-derived protein and plays a significant role in meeting global nutritional requirements. In many regions, aquaculture activities are predominantly managed by middle-aged to elderly farmers who tend to rely on conventional, labor-intensive production methods. The limited integration of advanced technologies in these traditional farming systems often constrains productivity, efficiency, and scalability within the sector (Islam et al., 2024). In Palembang, South Sumatra, *Channa striata* is one of the most consumed freshwater species and holds significant economic and cultural value for local communities (Anggraeni et al., 2023). However, local small-scale farmers have recently experienced declines in both the quality and quantity of farmed *Channa striata*, while market

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demand continues to increase. To meet the demand for Channa striata in Palembang, supplies are often imported from other regions, such as Kalimantan, Riau, and Papua. This indicates a gap in local production capacity and quality control.

Successful *cultivation of C. striata* requires a stable aquatic environment supported by continuous monitoring of key water quality parameters, such as pH, temperature, turbidity, and dissolved oxygen (Laboni et al., 2024). Traditional monitoring practices are predominantly manual and rely on handheld meters and visual inspection. These measurements are typically conducted periodically and depend heavily on farmer availability, making them inefficient for modern aquaculture systems that require continuous supervision. Rapid water quality fluctuations may occur within minutes; however, manual checks are often performed only two to three times per day, preventing the early detection of critical conditions. Consequently, farmers frequently respond too late, after fish exhibit stress symptoms or experience mass mortality.

Field observations at the partner hatchery (Kandang Om Bobby) indicated that water quality failures during spawning and fry-rearing stages can result in fry mortality rates of up to 40%, leading to substantial economic losses and discouraging farmers from expanding snakehead aquaculture. These risks highlight the urgent need for affordable, real-time monitoring, and early warning systems that enable faster corrective actions. These limitations demonstrate that manual approaches are no longer adequate for current aquaculture practices (Fernandes & DMello, 2025).

Recent advances in Internet of Things (IoT) technology have enabled the development of smart aquaculture monitoring systems capable of providing real-time sensing and automated alerts (Prapti et al., 2021; Kumar et al., 2022; Yang et al., 2025). However, most existing systems are designed for commercial or industrial farms, requiring high investment costs, complex installation, subscription-based platforms, and advanced technical skills. Consequently, these systems are rarely adopted by small-scale farmers. To address this gap, the Channa Sense monitoring system was developed as a simplified and cost-adapted IoT solution specifically designed for smallholder snakehead (Channa striata) farmers (Talukdar et al., 2025).

To provide a more accessible solution, the Channa Sense system was developed as an Internet of Things (IoT)-based monitoring device specifically tailored for *C. striata* farming. Positioned among existing aquaculture IoT technologies, Channa Sense emphasizes low cost, plug-and-play installation, minimal maintenance, and a simplified mobile interface that is easy to operate for farmers with limited digital literacy. Unlike commercial platforms that target large-scale automation, this system prioritizes practicality and usability for smallholder hatcheries. This positioning makes Channa Sense more suitable and sustainable for community-based aquaculture contexts.

Despite the rapid development of smart aquaculture technologies, the awareness and adoption of digital monitoring systems among small-scale fish farmers remains limited. A preliminary survey and interviews besides involved the main partner of this program (pak Bobby as the owner of Kandang Om Bobby) also involved 30 fish farmers from Palembang, Indralaya, and Musi Banyuasin. Their production is generally small-scale and conducted using aquaria or small ponds for spawning and fry nursing. Most of the fish farmers (67%) involved in the assessments had only a junior high school background. From the interviews, most of them stated that they did not know about fish technology that could be applied to help them monitor and control fish aquaculture.

In contrast to previous outreach activities that focused primarily on knowledge dissemination without any hands-on engagement, this community service program, which involved the direct participation of the participants in the technology, adopted a participatory outreach approach consisting of preliminary socialization, technical training sessions, live demonstrations, guided system installation, an intensive workshop, and continuous mentoring over a 3-month period. These staged activities were intentionally designed to promote active farmer participation, gradual skill development, and sustainable technology adoption.

Accordingly, the objectives of this community service are specifically to: (1) assist the partner hatchery (Kandang Om Bobby) in reducing fry mortality through the implementation of the Channa Sense real-time monitoring system; (2) improve farmers' knowledge and practical skills in water quality management and the operation of Internet of Things (IoT)-based monitoring technology; and (3) support the partner hatchery in improving production performance and increasing potential revenue per production cycle.

Therefore, this study documents and evaluates the implementation of the Channa Sense-based training and mentoring program and assesses its effectiveness in strengthening technological adoption, farmer capacity, and the sustainability of community-based aquaculture practices, especially at Kandang om Bobby and among fish farmers around Palembang, South Sumatra.

MATERIALS AND METHODS

Materials

This community service activity utilized the Channa Sense smart aquaculture monitoring system

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as the primary medium for technology dissemination and practical training. Rather than focusing on the technical specifications of each sensor component, the system was introduced as an integrated Internet of Things (IoT)-based solution designed to assist small-scale snakehead farmers in monitoring and stabilizing water quality parameters in real time. The system was demonstrated in Kandang Om Bobby's breeding aquariums and fishpond environments to ensure contextual understanding and applicability for participants.

Methods

This community service program was designed as a structured technology-assisted empowerment intervention grounded in the experiential learning approach (Kolb & Kolb, 2009). The implementation of this community service program was carried out through three main phases: pre-implementation, implementation, and evaluation. These phases were designed in accordance with the experiential learning framework, which emphasizes learning through direct experience, reflection, conceptual understanding, and practical application. This approach was considered appropriate because most participating farmers had limited exposure to digital technologies, requiring hands-on and practice-oriented learning methods. The absence of continuous monitoring in previous aquaculture was identified as the critical leverage point. Therefore, the intervention focused on introducing a low-cost, user-friendly real-time monitoring system combined with structured capacity building. This framework was selected because the target beneficiaries, small-scale snakehead (Channa striata) farmers, demonstrated limited prior exposure to digital monitoring systems and predominantly relied on manual, experience-based water quality management. Rather than applying a top-down dissemination model, the intervention positioned farmers as active co-learners.

RESULTS AND DISCUSSION

Pre-Implementation Phase

The pre-implementation phase was conducted to identify technical constraints, assess farmer readiness, and formulate a context-appropriate intervention model. Initial field observations were conducted at the partner hatchery (Kandang Om Bobby) to examine spawning practices, fry-rearing systems, water management routines, and monitoring frequency (Fig. 1). Observations confirmed that water quality assessment relied solely on manual measurements using handheld meters and visual inspection, typically conducted twice daily. There is to continuous or real-time monitoring mechanism was in place. To control the temperature Pak Bobby used the stove and boiling pot as shown in Fig.1 (c). While the field observations highlighted technical limitations in water quality management, understanding the social and educational characteristics of farmers was equally essential to determine the feasibility of introducing digital monitoring technology, Channa Sense. Therefore, beyond assessing infrastructure constraints, this phase also aimed to evaluate the human capacity and readiness of potential technology users.



(a) Spawning Room (b) Spawning Tank (c) Heating Stove and Water Boiling Pot

Fig. 1. The situation of Kandang Om Bobby

To better understand the factors influencing potential technology adoption, a structured baseline survey and interviews were administered to 30 small-scale *Channa striata* farmers from Palembang, Indralaya, and Musi Banyuasin. The demographic profile revealed that 67% of participants had a junior high school education background, 27% had senior high school education, and 7% held a diploma qualification. On average, farming experience ranged from three to five years, and production was generally conducted at the micro- to small-scale levels using aquarium-based spawning and fry-rearing systems. Importantly, none of the respondents had prior experience with digital or sensor-based monitoring systems.

These demographic and baseline characteristics were considered significant because education level and farming experience are commonly associated with technology adoption behavior in smallholder contexts. The intervention model was designed to actively involve local aquaculture practitioners throughout the technology adoption process. Rather than positioning farmers as passive recipients of information. The findings indicated limited exposure to digital devices and suggested that successful intervention would require simplified technical delivery, hands-on practice, and sustained mentoring rather than one-time

Implementation Phase

The implementation phase consisted of a structured series of outreach and technical activities integrating socialization, technical presentation,

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workshops, live demonstrations, hands-on practice, and continuous mentoring. The learning design followed the experiential learning cycle: namely, concrete experience, reflective observation, abstract conceptualization, and active experimentation. During this phase, participants were introduced to the basic concepts of water quality monitoring, sensor operation, and the interpretation of real-time data displayed through the smartphone interface.

One of the implementation phases, namely, a workshop, was conducted at the Manpower Department of Palembang (*Dinas Ketenagakerjaan*) and Kandang Om Bobby. It was attended by 37 participants, including students, fish farmers, and community members, as documented in Fig. 2. As the Master of Ceremony of workshop (Fig. 3), Mr. Rediyan Deddy Umrien, SE, MM, Head of Manpower Department at his opening speech encouraged participants to view the Channa Striata cultivication as an opportunity to strengthen both local food security and economic resilience.



Fig. 2. Workshop documentation



Fig. 3. Rediyan Deddy Umrien, SE, MM , Head of Manpower Department at his opening speech

The program commenced with a socialization and problem identification session led by the project team leader (Fig. 4). This session introduced the objectives of the community service program, discussed recurrent challenges in hatchery management, and emphasized the importance of stable water quality during spawning and fry-rearing stages. Participants were invited to share their experiences related to mortality incidents and delayed response to water quality changes. This stage facilitated reflective awareness of existing management gaps.



Fig. 4. Dr. Nyayu Latifah Husni opened the activity

The technical session was delivered by two main resource persons (Prof. Muslim and Rici Riansyah) from the multidisciplinary team. The IoT engineering specialist delivered the topic "Design and Operation of *IoT-Based Real-Time Monitoring Systems," explaining sensor components, data transmission mechanisms, calibration procedures, and mobile application interfaces of the Channa Sense* system (Fig. 5). The IoT engineering specialist delivered the topic "Design and Operation of IoT-Based Real-Time Monitoring Systems," explaining sensor components, data transmission mechanisms, calibration procedures, and mobile application interfaces of the Channa Sense system (Fig. 6). The material was delivered using simplified technical explanations and contextual case examples to accommodate the educational background of participants.

In addition to the two keynote speakers, as shown in Fig. 7, Bobby (the owner of Kandang Om Bobby) highlighted the significant market gap for snakehead fish (*Channa striata*) in Palembang, where the daily demand reaches 10 metric tons, but the local supply only meets approximately 1 metric ton. The high value of snakehead fish is largely due to its albumin content (Mustafa et al., 2012), creating strong business potential in breeding and grow-out operations.

In breeding, he noted that very few farmers in Palembang engage in snakehead fish spawning, with most fry supplied from Lampung. The weekly

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market demand for fry is approximately 100,000, while local production is only 40,000. By integrating Channa Sense technology, water quality, temperature, and pH can be effectively controlled, reducing fry mortality from 40% to 5%.



Fig. 5. Prof. Muslim elucidated Channa Striata



Fig. 6. Riansyah demonstrated othe type of Channa Sense technology

Traditionally, broodstock is sourced from the wild or markets and is adapted for one to four weeks before release into ponds for natural pairing. The diet includes *gondang* snails, water fleas (for high protein), tubifex worms, and eventually pellets after 14 days. At one month, fry reach 4–6 cm, an ideal size for sale to grow-out farmers. Snakehead fish are practical to raise for grow-out as they can survive in various environments, including drums, old refrigerators, or buckets, provided the enclosures are covered. The business can be divided into consumption and medicinal markets.

Bobby also pointed out opportunities in the supply chain, including collection and distribution, stating that "breeding, grow-out, and supply are interconnected opportunities" that can strengthen both economic and community development. The interactive question-and-answer session provided participants with the opportunity to explore both the biological aspects of snakehead fish (Channa striata) cultivation and the practical application of Channa Sense technology.



Fig. 7. Bobby shared his experienced in fish farming

Prof. Muslim answered questions related to spawning and pond management. A participant asked whether aquatic plants such as lotus are necessary for egg laying. He clarified that snakehead fish differ from species such as catfish because their eggs float and do not require substrates such as stones or leaves. He further emphasized that snakeheads can be cultured in both open and closed systems; however, "sufficient light, whether from sunlight or lamps, is essential" for successful growth and reproduction. When asked about pond selection, he advised that tarpaulin ponds are more suitable for beginners because of their affordability, mobility, and ease of preparation compared with cement ponds.

Mr. Bobby focused on feeding strategies, pond size, and comparisons with catfish. He explained that feed requirements vary depending on the diet, with pellets, snails, or chicken breast as options, noting that snails provide a cost-effective alternative. The stocking density should be approximately 200 fish per cubic meter; however, he warned that snakeheads are carnivorous and may exhibit cannibalism underfed. He highlighted key differences from catfish, particularly their slow feeding behavior and tendency to chew, which makes regular water replacement important to maintain water quality.

Mr. Rici Riansyah discussed the practical use of Channa Sense. He explained that basic monitoring devices cost approximately 4–5 million rupiah, whereas more advanced systems, such as those used in larger facilities, are more expensive. He noted that although the system includes supporting devices for water neutralization, its main function is monitoring, with an automatic water replacement feature to maintain stability. This dialogue highlighted practical

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insights into snakehead aquaculture and demonstrated the adaptability of Channa Sense for different scales of fish farming, as shown in Fig. 8.



Fig. 8. Participant conveyed the questions

Pre- and Post-Questionnaires

The participants were asked to complete a questionnaire before and after the workshop. A total of 37 responses were collected and analyzed. This approach provided a systematic way to evaluate knowledge gains, participant satisfaction, and the overall impact of community service activities.

The questionnaire contained both multiple-choice and Likert-scale questions to assess participants' knowledge, perceptions, and readiness to adopt smart monitoring technology. For the pre-questionnaires, majority of respondents from the survey conducted after the socialization were male (51.35%), had a high school/vocational school education level (48.65%), and were entrepreneurs/MSMEs (40.54%).

The workshop included a hands-on session at Kandang Om Bobby, where participants directly observed the application of Channa Sense technology. The participants were introduced to sensor kits and had the opportunity to view live data readings. The demonstration showcased how microcontrollers integrate with data displays to monitor water quality parameters (Akhter et al., 2021; Mustafa et al., 2021). Participants also explored the thermal isolation cabinet, integrated aquariums, solar panels, sensors, actuators, and the control system linked to a monitoring interface. This session provided a practical understanding of how the technology operates in real environments, bridging theoretical concepts with tangible field applications (Fig. 9 and Fig. 10).

To ensure sustained adoption, continuous mentoring was conducted for three months following initial installation. The mentoring process included periodic site visits, remote technical assistance, monitoring of system utilization, and consultation sessions to support adaptive management decisions based on sensor data. This extended assistance aimed to strengthen technical confidence and facilitate the gradual integration of digital monitoring into routine hatchery management.



Fig. 9. Participants observed the thermal and integrated aquariums of Channa Sense technology



Fig. 10. Participants observed the fish ponds

Evaluation Phase

The evaluation phase was designed to assess learning achievement, operational competence, and early-stage adoption behavior. This phase phase was conducted to assess the effectiveness of the community service program. This evaluation involved pre-test and post-test questionnaires to measure participants' understanding of IoT-based monitoring systems and observations of operational improvements at the partner hatchery after the installation of the Channa Sense system. The evaluation framework focused on measuring changes in cognitive understanding, technical skills, and behavioral intention to continue using the system in daily hatchery operations.

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Table 1. Pre-test and post-test results

Indicator	Scale	Pre-workshop (%)	Post-workshop (%)
How familiar are you with Channa Sense technology?	Not aware at all	56.76	–
	Heard of it but no understanding	29.73	–
	Understand	–	35.14
	Moderately understand	8.11	54.05
	Fully understand	2.70	10.81
What do you think Channa Sense technology is?	Not aware at all	48.65	–
	Water Quality Monitoring Technology	13.51	60.42
	Automatic Spawning Assistance Device	24.32	29.17
	Aquaculture Information System	8.11	10.42
How interested are you in using Channa Sense technology?	Interested	21.62	24.32
	Moderately interested	56.76	67.57
	Slightly interested	2.70	10.81
	Not interested	2.70	2.70

Awareness and Digital Literacy Barriers

As shown in Table 1, before the program, more than half of the respondents (56.76%) were unaware of Channa Sense technology. This high percentage can be explained by limited access to information and low digital literacy among small-scale fish farmers. This high percentage can be explained by limited digital literacy and lack of prior exposure to sensor-based monitoring devices. Demographic data collected during the pre-implementation stage showed that most participants had only secondary education (approximately 67% high school or below), an average farming experience of 3–5 years, and 0% had previously used any sensors or automated devices. Water quality assessment relied entirely on manual observation conducted three times per day. These characteristics indicate that low awareness levels resulted primarily from limited access to technology and information, rather than resistance to innovation.

Many participants were initially unfamiliar with IoT-based monitoring systems and had never used digital technologies for aquaculture management. This reflects a common phenomenon known as the second-level digital divide, in which access to digital devices such as smartphones exists, but the knowledge and skills required to utilize specialized digital technologies remain limited. This finding confirms the urgency of introducing a simple and affordable IoT solution tailored to small-scale farmers.

Knowledge Improvement After Experiential Learning

After the workshop, participants' understanding improved substantially. A total of 54.05% reported moderately understanding the technology, and 10.81% reported fully understanding it. Although the proportion of "fully understand" appears relatively small, this outcome is reasonable because the workshop represented the participants' first exposure to IoT-based systems. Technical mastery of sensor calibration, data interpretation, and actuator control typically requires repeated practice and long-term use rather than a single-day session. Therefore, most participants achieved foundational or intermediate competence levels rather than full mastery. This result demonstrates that the experiential learning approach was effective in building basic technological literacy, while continued mentoring is necessary for advanced skill development.

Perception of System Function

Perceptions regarding the nature of Channa Sense also improved. Recognition of the system as water quality monitoring technology increased from 13.51% to 60.42%. This shift indicates that participants successfully understood the core purpose of the system, reflecting improved technological awareness and problem identification related to water quality management.

Practical Impact on Partner Hatchery (Kandang Om Bobby)

In addition to improving knowledge, measurable operational benefits were observed at the partner hatchery (Kandang Om Bobby), where the system was directly implemented. Prior to the intervention, monitoring was manual and conducted only three times per day, often resulting in delayed responses to sudden environmental fluctuations. Fry mortality during spawning and early rearing reached approximately 40%.

After applying real-time monitoring and alert-based responses through Channa Sense, mortality decreased to approximately 5%–10%. This represents

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Table 2. Changes resulting from community service activities

Aspect	Before Program	After Program	Improvement
Technology awareness	56.76% unaware	64.86% understand	Literacy increased
Monitoring method	Manual (3×/day)	Real-time sensors	Faster detection
Response time	Delayed	Immediate alerts	Risk reduced
Fry mortality	~40%	5–10%	Survival rate +30–35%
Monitoring workload	Frequent manual checks	Automated alerts	Time saving
Farmer confidence	Moderate	Higher	Adoption readiness
Estimated economic impact per production cycle	-	IDR 5,000,000 per cycle	Increase revenue potential

an improvement in the survival rate of approximately 30–35%, potentially increasing the number of marketable fry and reducing production losses. Farmers also reported reduced monitoring time and faster corrective actions when abnormal parameters were detected.

The reduction in fry mortality also contributed to measurable economic benefits. Based on production records from the partner hatchery, improvements in fry survival rates increased the number of marketable fish per production cycle. This improvement generated an estimated additional revenue of up to IDR 5,000,000 per production cycle, demonstrating the practical economic value of implementing real-time monitoring technology in small-scale snakehead aquaculture (Kantal et al., 2025).

These outcomes demonstrate that the program generated not only educational improvements but also tangible technical and economic benefits for the partners. Table 2 confirms that community service activities produce measurable improvements in knowledge, operational efficiency, and production outcomes.

System Interface (UI/UX) and Usability

To address digital literacy barriers, the Channa Sense monitoring interface was designed to be simple and user-friendly to accommodate farmers with limited digital literacy. The system displays real-time data for several key water quality parameters, including temperature, pH, dissolved oxygen, and turbidity. These parameters are visualized through a smartphone-based dashboard that allows farmers to easily interpret current water conditions. The interface also provides alert notifications when parameter values exceed recommended thresholds, enabling farmers to take immediate corrective actions..

The interface provides simple buttons to activate the mode: manual or automatic (Fig. 11 (a)). In the manual mode, operators can push the button that they want to control, such as a control valve, suction pump, filling pump, or heater (Fig. 11 (b)). In addition, the Channa sense interface displays real-time numerical readings such as temperature, pH, dissolved oxygen, and turbidity (Fig.11 (c)). It also displays and sends alerts when parameters exceed safe thresholds. This minimal and intuitive design reduces cognitive load and enables farmers to quickly interpret system conditions without advanced technical knowledge. Participants reported that this user-friendly design improved their confidence and willingness to adopt the technology.



(a) Dashboard



(b) Example of control valve menu



(c) Real time numerical data

Fig. 11. Example of channa sense interface

Interest in utilizing the technology increased slightly after the workshop. However, the intention to adopt remained moderate. The interviews revealed

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that equipment costs, maintenance concerns, and limited experience with electronics were the main constraints. These findings suggest that future programs should include extended mentoring, financial support, and cooperative ownership schemes to promote wider and sustained adoption.

Overall, the results demonstrate that the community service activity successfully improved awareness, technological understanding, and initial readiness to adopt IoT-based monitoring, while also yielding improvements in both operational performance and economic sustainability at the partner site. These outcomes indicate that the Channa Sense intervention is both educationally effective and practically beneficial for small-scale aquaculture communities.

CONCLUSION

This community service program successfully strengthened technological literacy and operational capacity among small-scale Channa striata farmers through the implementation of an Internet-of-Things (IoT)-based Channa Sense monitoring system. The success of the program can be evaluated through several measurable indicators, including improvements in participants' technological understanding, reductions in fry mortality rates, and increased production efficiency at the partner hatchery. The main contribution of this activity is bridging the digital divide in community-based aquaculture by introducing an affordable, context-adapted real-time water quality monitoring solution combined with structured experiential learning and sustained mentoring.

Additionally, some participants expressed concerns regarding equipment costs and maintenance requirements, which may influence long-term adoption. The measurable success of the program was demonstrated through both educational and operational indicators. Awareness of the system increased significantly, with 64.86% of participants reporting moderate to full understanding after the workshop, compared to 56.76% who were previously unaware of the technology. Recognition of the system as a water quality monitoring device increased from 13.51% to 60.42%. At the partner hatchery (Kandang Om Bobby), the implementation of real-time monitoring reduced fry mortality from approximately 40% to 5–10%, representing an estimated survival improvement of 30–35%. The improvement in fry survival generated additional revenue of up to IDR 5,000,000 per production cycle, enhancing the economic sustainability of the operation. Additionally, the monitoring workload decreased due to automated alerts, and the response time to water quality fluctuations became immediate rather than delayed.

Despite these positive outcomes, several limitations were identified. First, the intervention period was limited to three months, which restricts the long-term evaluation of sustained adoption and economic scalability. Second, the program involved a relatively small sample (30 farmers), limiting generalizability. Additionally, some participants expressed concerns regarding equipment costs and maintenance requirements, which may influence long-term adoption.. These findings indicate that technological effectiveness alone is insufficient without continued support mechanisms. Additionally, some participants expressed concerns regarding equipment costs and maintenance requirements, which may influence long-term adoption. Additionally, some participants expressed concerns regarding equipment costs and maintenance requirements, which may influence long-term adoption.

Future community service initiatives should focus on extended mentoring cycles, cooperative-based equipment-sharing schemes, and simplified maintenance training modules to enhance long-term sustainability. Further development of the Channa Sense system may include cost optimization, integration with predictive analytics, and expansion into broader hatchery management functions. Strengthening collaborations with local governments and aquaculture cooperatives could also facilitate wider diffusion and financial accessibility.

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